

Advanced Modeling with SAM 2010.11.9

Webinar Talking Points, February 8 2011

Agenda

- Comparing cases: Tabs and parametrics
- Optimization
- Uncertainty analysis
- Scripting with SamUL
- Excel Exchange
- Calling SAM from Python, C, MATLAB, and VBA programs

Comparing cases: Tabs and parametrics

- You can set up different analysis scenarios as cases in a SAM file
- This makes it possible to compare inputs and outputs for the scenarios using the tabs at the top of the main window.
- The parametric simulation option makes it possible to create graphs of different analysis scenarios.

Optimization

Example: Parabolic Trough Solar Multiple

Step 1. Specify the power block nameplate capacity

SAM considers the system's nameplate capacity to be the values displayed as **Estimated net output at design** on the Power Cycle page for the physical trough model, and the Power Block page for the empirical trough model.

1. Specify the power cycle's **Design gross output**.

This value does not account for parasitic losses.

The design point output variable determines the solar field aperture area when you use the solar multiple to specify the solar field size on the Solar Field page.

2. Specify the **Estimated gross to net conversion factor**.

SAM calculates the estimated net output at design value as the product of the conversion factor and the design point electric output.

The **Estimated net output at design (nameplate)** is equivalent to the system's nominal or rated capacity, which SAM uses to calculate capacity-related calculations including the system capacity factor, and capacity-based incentive payments.

3. Specify the **Condenser type** under **Cooling System**.

Evaporative is for wet cooling, and Air-cooled is for dry cooling.

SAM calculates the quantity of water required for cooling and reports it in the hourly results.

Step 2. Determine the Reference Radiation Value

1. On the Thermal Storage page, change Full load hours of TES to zero.

The hours of TES variable is the number of hours that the TES can drive the power block at its nameplate capacity

2. On the Climate page, choose a location: **Sevilla**

3. On the Solar Field page, under **Collector Orientation**, specify a **Collector tilt** value and a **Collector azimuth** value.
An azimuth of zero is oriented toward the equator in both the north and south hemispheres.
4. Click Run all simulations.
You do not need to characterize the rest of the system, or specify costs, etc. This step is just to calculate the incident irradiance values.
5. When simulations are complete, click Export and view data, and then **View Hourly Time Series (DView)**.
6. Use DView to find the maximum value of **Collector DNI-x-CosTh**.
7. On the Solar Field page, enter the maximum incident DNI value for **Irradiation at design**.

Step 3: Perform a parametric analysis on the solar multiple

1. Click Configure simulations, and then **Parametrics**.
2. Click **Add Parametric Simulation**.
3. Under **Parametric Simulation Setup**, click **Add**.
4. In the Choose Parametrics window, under **Physical Trough Solar Field**, check **Solar Multiple** and click **OK**.
5. Under **Parametric Simulation Setup**, click **Edit**.
6. In the Edit Parametric Values for 'Solar Multiple' window, type the following values:
Start Value 1
End Value 2.5
Increment 0.25
7. Click **Update** and then **OK**.
8. Click Run all simulations.
9. When simulations are complete, on the Results page, display a graph of LCOE vs solar multiple to find the solar multiple that results in the lowest LCOE.

If the minimum is at the low or high end of the graph, repeat Steps 6 through 9, adjusting the range of solar multiple values as needed to find the minimum.

10. On the Solar Field page, type the optimal solar multiple value in **Solar multiple**.

Step 4. Determine the Optimal Solar Multiple for a System with Storage

1. Continuing from Step 10 above, display the Parametric simulation setup page, and add the **TES Full load hours of TES variable** to the parametric variables list.
This optimization requires defining both the solar multiple and storage capacity variables as parametric variables.
2. Assign the range of values 0 to 12 hours in 4 hour increments to the storage capacity.
3. Click Run all simulations.
The 25 simulations required for this analysis will take several minutes depending on the speed of your computer.
WHILE SIMULATIONS ARE RUNNING, DISCUSS LINKAGES: EXAMPLE OF LINKING LOCATION TO ARRAY TILT
- STOP SIMULATIONS, SWITCH TO TROUGH SAMPLE FILE
4. When simulations are complete, on the Results page, display a graph showing LCOE vs solar multiple for each storage capacity value.
If necessary, refine the ranges of the parametric variables so that you can identify the minimum LCOE for each storage capacity on the graph
5. On the Thermal Storage page, type the desired number of hours of storage capacity in the **TES Full load hours of TES** box.

6. On the Solar Field page, type the optimal solar multiple value for the desired storage capacity in the **Solar multiple** box.

Uncertainty Analysis

- SAM runs many simulations so that you have enough data points for output variables of interest to examine effects of variation in inputs on results
- Good for sensitivity analysis and uncertainty analysis
- A better option than Sensitivity option
- Requires some familiarity with statistics to use effectively
- Delta R2 – coefficient of determination, r^2 – a measure of the fluctuation of an output variable over a range of values of an input variable
- Graph shows that capacity factor is most sensitive to production well flow rate
- When you set up a statistical simulation, the scatter plot option becomes available in the Edit Graph window
- Graph shows pattern in relationship between capacity factor and permeability of the resource

Geothermal Uncertainty Example

- For geothermal systems, production depends on the temperature of the resource and permeability of the rock.
- For preliminary analyses, available resource data for temperature and permeability is likely to be uncertain.
- On the design side, production well flow rate is an important parameter.
- This example examines the relative sensitivity of the plant's performance to these uncertain parameters using SAM's uncertainty simulation option.

Step 1: Create a New Geothermal Case

1. Create a new case: Geothermal/Utility IPP
2. Step through input pages to the resource
3. Click "Lookup temp and depth for a location" (*must be internet connected for this to work*)
 - a. Query for Denver, CO
 - b. Click on Row 5 to apply 7500m and 221.1 degC as the current inputs
 - c. Close the dialog
4. On Plant and Equipment page, note production well flow rate.

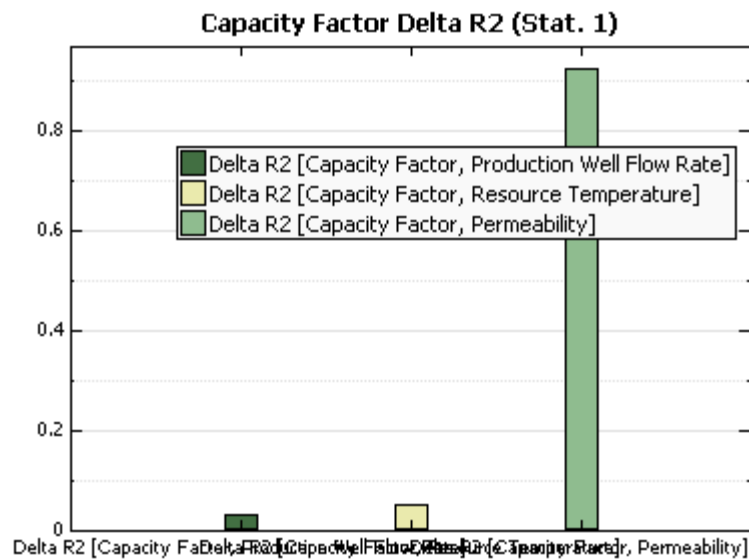
Step 2: Set up the Uncertainty Parameters

1. Click Run.
2. Click Configure Simulations button and show Statistical simulation page.
3. Add a statistical simulation.
4. Under Output Metrics, click Add, and check Plant Lifetime Output and Capacity Factor.
5. Under Input Distributions, click Add, and check the following:
 - a. Geothermal Resource/Resource Temperature
 - b. Geothermal Resource/Permeability
 - c. Geothermal Plant and Equipment/Production Well Flow Rate
6. Double click each variable to and select a distributionlist:
 - a. Resource Temperature: Normal, Mean=220, StdDev = 20
 - b. Production Well Flow Rate: Uniform, Min=60, Max=80

- c. Permeability: Lognormal, Mean=0.05, ErrorF = 2
7. Note that these are guesses at the actual uncertainties for demonstration. Choosing appropriate distributions is tricky and requires some trial and error.
8. Change the number of sampled values from 100 to 200 (Geothermal will run relatively quickly).
9. And change the seed value to 123 so that the result is reproducible.
10. Save the file before continuing in case something goes wrong
11. Click Run.

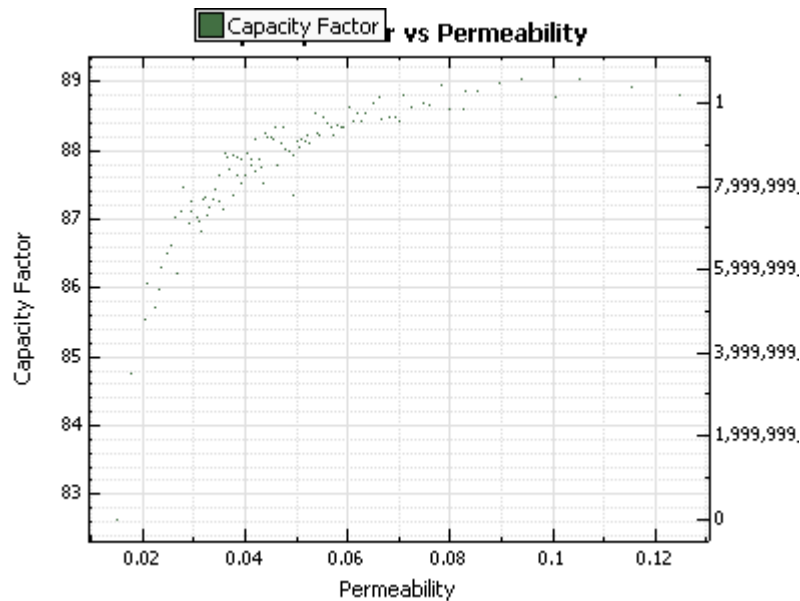
Step 3: Review Results

1. On the Results page, click the Capacity Factor Delta R2 graph:



The sensitivity of the independent variables can be represented by $\Delta R2$, the change in the coefficient of determination when a new independent variable is added to the model. The value of $\Delta R2$ describes the percentage of the uncertainty or variability in the simulated metric that is caused by the uncertainty in each input variable. In addition to $\Delta R2$, the standardized regression coefficient (β) is another statistical measure that evaluates the relative contributions of each input parameter to the magnitude of the dependent variable (as opposed to the variability of the dependent variable). The sign of β also gives the direction of correlation. The importance ranking of the independent variables using either $\Delta R2$ or β are typically the same.

2. Now click Add New Graph to create a scatter plot showing relationship between Capacity Factor and Permeability:



Edit Graph

Graph Data

Choose Simulation: **Statistical Analysis 1**

X Value: **Input(Permeability)**

Y1 Values:

- ☐ Analysis Period (years)
- ☐ Annual Energy
- ☐ Annual Fuel Usage (kWht)
- ☐ Annual Water Usage
- ☐ Capacity Factor
- ☒ Capacity Factor
- ☐ Debt Fraction
- ☐ Input(Permeability)
- ☐ Input(Production Well Flow Rate)
- ☐ Input(Resource Temperature)
- ☐ Installed Cost (\$)

Y2 Values:

- ☐ Analysis Period (years)
- ☐ Annual Energy
- ☐ Annual Fuel Usage (kWht)
- ☐ Annual Water Usage
- ☐ Capacity Factor
- ☐ Capacity Factor
- ☐ Debt Fraction
- ☐ Input(Permeability)
- ☐ Input(Production Well Flow Rate)
- ☐ Input(Resource Temperature)
- ☐ Installed Cost (\$)

Graph Type

- ☐ Bar Graph
- ☐ Stacked Bar Graph
- ☐ Line Plot
- ☐ Tornado Chart
- ☐ Contour Plot
- ☐ Histogram/CDF
- ☒ Scatter Plot

Properties

Title: **Capacity factor vs Permeability**

X Label: **Permeability** ☒ Show X Values

Y1 Label: **Capacity Factor** ☒ Show Y1 Values

Y2 Label: ☒ Show Y2 Values

Text Size: 0 X Tick Spacing 1

Thickness: 5 ☒ Show Legend

☒ Show Coarse Grid ☒ Show Fine Grid

Min Max

☐ Set X Min/Max 0.00937 0.1304

☐ Set Y1 Min/Max 82.325 89.374

☐ Set Y2 Min/Max -5.3037 1.1137

Color Schemes:

Y1: **Default**

Y2: **Pastels**

Help... Accept Cancel

Scripting with SamUL

- Built-in scripting language
- Allows you to automate complex analysis tasks
- Read and write text files (including csv)
- Set values of input variables
- Read output variables
- Perform calculations
- User guide in Help menu
- Examples in sample file

- Email user support for help

Excel Exchange

- Allows you to use Excel to calculate values of SAM input variables

Example

- PV Watts Case
- Calculate DC rating based on roof area
- User Variable 1 is roof area
- Set up worksheet in Excel
- input: cell range "roofarea"
- output: cell range "dcrating", $=\text{roofarea} \times 140 / 1000$
- Set up Excel Exchange in SAM
- Browse for "area-to-kw.xlsx"
- Add DC Rating, User Variable 1
- Capture DC rating from dcrating
- Send User Variable 1 to roofarea
- Run

Trough Cost Model

- Download documents from SAM website,
https://www.nrel.gov/analysis/sam/cost_data.html

Calling SAM from Python, C, MATLAB and VBA programs

Generating Python Code

1. Start SAM and create a new case: Photovoltaics, Component-based Models, Residential Loan.
2. Run the case to see the results.
3. Create the Python code: Click Case, Advanced, Generate Python.
4. Save the file to a folder on your desktop: \python_example\my_pv_case.py.
5. Click No at the prompt to view the file.
6. Open the folder on your desktop to see the following two files: pysam.py and my_pv_case.py. The file pysam.py is the Python/SAMSIM.dll interface code that is always generated. The my_pv_case.py file is the file that contains all of the inputs.

Running the Python Program

1. Open a command prompt (Start Menu>Run, type 'cmd.exe' and press Enter).
2. Navigate to the desktop\python_example folder: cd Documents and Settings\username\Desktop\python_example.
3. Try to run it by typing python my_pv_case.py. It might fail because it's looking for samsim.dll. To fix this, copy samsim.dll to the python_example folder from the SAM install folder.
4. When the program runs, you should see:

```
C:\Documents and Settings\adobos\Desktop\python_example>python my_pv_case.py
TRNSYS16 (IVF-SAM) 31OCT10
TRNSTART
10 %
20 %
30 %
40 %
50 %
60 %
70 %
```

```

80 %
90 %
100 %
TRNEND
Lcoe(real)= 12.7051132298
Lcoe(nom)= 15.4848167856
E_net= 6987.46656644

```

5. C:\Documents and Settings\adobos\Desktop\python_example>
6. Close SAM in the background, and run again to show that you don't need SAM open to run the simulation

Changing SAM inputs in the Python Code: Array Tilt Angle

1. At the command prompt type "notepad my_pv_case.py." Notepad should open with the Python code that SAM generated. This file sets up all of the inputs as they were originally set in the SAM file from which it was created.
2. Replace the simulation calls at the bottom of the file with a loop that changes the tilt:

```

cxt = sam.create_context('dummy')
setup_case_inputs(cxt)
sam.set_s(cxt, 'sim.hourly_file', 'C:/Documents and
Settings/adobos/sam_python/hourly.dat')
sam.set_s(cxt, 'trnsys.workdir', 'C:/Documents and Settings/adobos/sam_python')
sam.set_s(cxt, 'ptflux.workdir', 'C:/Documents and Settings/adobos/sam_python')
sam.set_s(cxt, 'trnsys.install_dir', 'C:/SAM/2010.11.9/exelib/trnsys')
sam.set_d(cxt, 'trnsys.timestep', 1.0)
sam.set_s(cxt, 'ptflux.exedir', 'C:/SAM/2010.11.9/exelib/tools')

for tilt in [10,15,20,25,30]:
    sam.set_d(cxt, "pv.array.tilt", tilt)
    cxt = simulate_context( cxt, 'trnsys.pv' )
    cxt = simulate_context( cxt, 'fin.res.loan' )
    print 'Tilt=',tilt
    print '  Lcoe(real)=',sam.get_d(cxt, 'sv.lcoe_real')
    print '  Lcoe(nom)=',sam.get_d(cxt, 'sv.lcoe_nom')
    print '  E_net=',sam.get_d(cxt, 'system.annual.e_net')

sam.free_context(cxt)

```

3. Run it again: python my_pv_case.py, and you will see it calculate the energy production at tilts of 10,15,20,25,30 and spit out the LCOE and ENet.

This technique could be use to call SAM over the web, or to run a huge parametric study that writes special output files etc.

The same integration can be done with Excel, MATLAB, and C.